X II

(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 701 309 A2

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
13.03.1996 Bulletin 1996/11

(51) Int. Cl.[6]: H01S 3/19, H01L 33/00, H01S 3/085

(21) Application number: 95113765.2

(22) Date of filing: 01.09.1995

(84) Designated Contracting States:
DE FR GB

(30) Priority: 02.09.1994 JP 210097/94

(71) Applicant: SUMITOMO ELECTRIC INDUSTRIES, LTD.
Osaka-shi, Osaka 541 (JP)

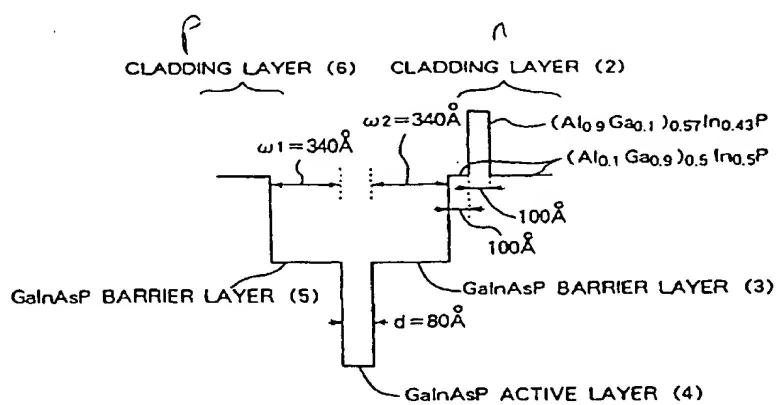
(72) Inventors:
- Katsuyama, Tsukuru, c/o Yokohama Works Yokohama-shi, Kanagawa 244 (JP)
- Yoshida, Ichiro, c/o Yokohama Works Yokohama-shi, Kanagawa 244 (JP)
- Hashimoto, Jun-ichi, c/o Yokohama Works Yokohama-shi, Kanagawa 244 (JP)
- Murata, Michio, c/o Yokohama Works Yokohama-shi, Kanagawa 244 (JP)

(74) Representative: Lehn, Werner, Dipl.-Ing. et al
Hoffmann, Eitle & Partner,
Patentanwälte,
Arabellastrasse 4
D-81925 München (DE)

(54) **Semiconductor laser diode**

(57) A semiconductor laser diode which can be applied to optical fiber amplifiers to attain a high reliability and can generate light having a wavelength of about 1 μm is provided. This semiconductor laser diode is formed on a GaAs substrate and has an active layer comprising a GaInAsP strained quantum well whose energy band gap is smaller than that of GaAs. Barrier layers each comprising GaInAsP whose band gap is greater than that of the active layer are bonded to the active layer through heterojunction. According to this structure, when the active layer and the barrier layers are grown, the amounts of supply of a Ga material and an In material can be controlled in a simple manner and a semiconductor laser diode having a high reliability can be realized.

Fig. 4



EP 0 701 309 A2

Description

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a semiconductor laser diode used for excitation light of optical fiber amplifiers, optical fiber amplifier system and a method of making the laser diode.

Related Background Art

As semiconductor laser diode technology has developed, various types of new laser diodes are proposed. Such a new laser diodes are described in U.S. Patent No. 5,389,396 or in the Extended Abstracts of the 54th Autumn Meeting of the Japan Society of Applied Physics pp. 1049, 1993.

SUMMARY OF THE INVENTION

In optical communication, when relays with optical fiber amplifiers which can directly amplifying the signal light are used, longer-distance transmission and larger capacity in optical transmission systems are obtained. Er-doped optical fiber amplifiers and Pr-doped fluoride fiber amplifiers can amplify the signal light.

In the Er-doped optical fiber amplifier, an optical fiber doped with erbium (Er) is used to amplify signal light at a wavelength band of 1.5 μm, while using a semiconductor laser diode having a wavelength of 1.48 μm or 0.98 μm as a pumping source for this amplification. The dopant in the optical fiber amplifier is excited by light of 0.98 μm semiconductor laser diode.

In the Pr-doped fluoride fiber amplifier, an optical fiber doped with praseodymium (Pr) amplifies the signal light at a wavelength band of 1.3 μm, while using a semiconductor laser diode having a wavelength of about 1.02 μm as a pumping source for this amplification.

A semiconductor laser diode with an oscillation wavelength of about 0.98 μm applied to such an optical fiber usually has a separate confinement heterojunction structure including a GaInAs strained quantum well active layer held between GaAs or GaInAsP barrier layers, and the structure is effective to confine carriers therein. This structure has been applied in order to prevent the threshold current from rising and so forth.

Nevertheless, the reliability required for the semiconductor laser diode used for the pumping source of the optical fiber amplifier is higher than that required for the conventional semiconductor laser diode having the GaInAs active layer and, accordingly, a semiconductor laser diode having a higher reliability is demanded as a pumping source.

An object of the present invention is to provide a semiconductor laser diode which can be applied to optical fiber amplifiers to attain a high reliability and can generate light having a wavelength of about 1 μm. A method of making such a semiconductor laser diode is provided also.

The present invention provides a semiconductor laser diode, which has a GaAs substrate and an active layer formed on the substrate. The active layer is comprised of a GaInAsP strained quantum well layer whose energy band gap is smaller than that of GaAs.

In one aspect, the active layer comprising the GaInAsP strained quantum well has a structure in which a barrier layer comprising GaInAsP whose energy band gap is greater than that of the active layer is formed with heterojunction.

In one aspect, the active layer and the barrier layer have substantially the same composition ratio of Ga:In.

In one aspect, the barrier layer has such a structure that receives, in close proximity to the active layer, a compression strain which is smaller than that applied to the active layer.

In one aspect, a semiconductor window layer whose energy band gap is greater than that of the active layer is grown on an end surface.

In one aspect, the oscillation wavelength of the semiconductor laser diode at room temperature is set not shorter than 0.96 μm.

In one aspect, the semiconductor laser diode is made in such a manner that, when the active layer and the barrier layer are grown, a Ga material and an In material are supplied with constant amounts so that both layers have substantially the same composition ratio of Ga:In.

In one aspect, a portion including said barrier layer and active layer is grown while being held between cladding layers. This portion and the cladding layers are formed by a material containing P.

In one aspect, the semiconductor laser diode is made in such a manner that, when the active layer, the barrier layer, and the cladding layer are grown, a Ga material and an In material are supplied with constant amounts so that all these layers have substantially the same composition ratio of Ga:In.

In the semiconductor laser diode in accordance with the present invention, in comparison to the case where GaInAs is used as an active layer, the amount of strain becomes greater at the same oscillation wavelength, thereby enabling

its characteristics to improve due to the strain. This effect becomes greater when the oscillation wavelength is not shorter than 0.96 µm. Also, since each of the active and barrier layers contains P, defects hardly occur at their interfaces during manufacture. Accordingly, the defects can be reduced. Further, since GaInAsP has a carrier-recombining velocity at its interface with a silicon nitride film (coating layer) or the like slower than that of GaInAs, reliability can be improved when an end-surface coating is effected.

When an active layer is grown as GaInAs having a thickness of about 80 angstroms and then, with its Ga:In composition ratio, a GaInAsP barrier layer is grown such that its lattice matches that of a substrate, the energy band gap of the barrier layer becomes so small that the original function (effect) of the barrier may be reduced. On the other hand, when the GaInAsP active layer of the present invention is applied, the energy band gap of the GaInAsP barrier layer can become large even when the Ga:In composition ratio is made constant. When the compositions of Ga and In in the active layer can be substantially the same as those of the barrier layers, the amounts of supply of Ga and In can be maintained at their constant levels. Accordingly, advantageous effects can be obtained in the manufacture in that manufacturing steps can be simplified and so forth.

The present invention will be more fully understood from the detailed description given hereinbelow and the accompanying drawings, which are given by way of illustration only and are not to be considered as limiting the present invention.

Further scope of applicability of the present invention will become apparent from the detailed description given hereinafter. However, it should be understood that the detailed description and specific examples, while indicating preferred embodiments of the invention, are given by way of illustration only, since various changes and modifications within the spirit and scope of the invention will be apparent to those skilled in the art from this detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1A is a vertical sectional view showing the structure of the semiconductor laser diode in accordance with the first embodiment of the present invention;

Figs. 1B and 1C are explanatory views showing profiles of energy band gaps in essential parts of the semiconductor laser diode of Fig. 1A in accordance with the first embodiment;

Fig. 2 is a chart comparing the characteristics of the semiconductor laser diode in accordance with the first embodiment with those of a semiconductor laser diode having GaInAs active layer;

Fig. 3 is an explanatory view showing an example of the method of making the semiconductor laser diode in accordance with the first embodiment;

Fig. 4 is an explanatory view showing the structure of the semiconductor laser diode in accordance with the second embodiment of the present invention with reference to a profile of energy band gaps in essential parts thereof;

Fig. 5 is an explanatory view showing an example of making the semiconductor laser diode in accordance with the second embodiment;

Fig. 6 is a flow chart showing the steps in the method of making the semiconductor laser diode in accordance with the third embodiment of the present invention; and

Figs. 7A - 7C are explanatory views showing the device structures according to the flow chart of Fig. 6.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The structure of the semiconductor laser diode and method of making the same in accordance with the first embodiment of the present invention will be explained with reference to Figs. 1A - 3.

Fig. 1A shows a cross-sectional structure of the semiconductor laser diode in which a direction perpendicular to the cleavage plane of the crystal is indicated as perpendicular direction z, a direction in which each semiconductor layer is superposed is indicated as vertical direction x, and a direction perpendicular to the xy directions is indicated as parallel direction y.

An n-type cladding layer 2 having a thickness of about 2 µm is grown on an n-type GaAs substrate 1. An active layer 4 is sandwiched between a first barrier layer 3 and a second barrier layer 5, and these layers are grown on the n-type cladding layer 2. A compressive stress is applied to the active layer 4.

A p-type cladding layer 6, an n-type current-blocking layer 10, a p-type GaInAsP buffer layer 7a, a p-type GaAs contact layer 7b and a p-type electrode layer 8 are successively formed.

On the back surface of the semiconductor substrate 1, an n-type electrode layer 9 is mounted. Though not depicted, the p-type GaAs contact layer 7b and the p-type electrode layer 8 are not formed within the range of about 20 µm from the periphery of the device of Fig. 1A.

When a part of the p-type GaAs contact layer 7b and p-type electrode layer 8 is removed in this manner, excitation current is prevented from flowing at the end surfaces of the device.

The n-type cladding layer 2 and the p-type cladding layer 6 are composed of AlGaInP. The p-type cladding layer 6 has a flat portion having a thickness of about 0.4 µm which is grown on the second barrier layer 5 as well as a mesa stripe portion having a thickness of about 2 µm and a width of about 1.5 µm. The rest of this layer is removed by pho-

tolithography and chemical etching and then the current blocking layer 10 composed of n-AlGaInP, whose crystal has grown again, is formed thereon.

Each of the first and second barrier layers 3, 5 comprises GaInAsP and is grown to a layer thickness of about 340 angstroms. The active layer 4 comprises GaInAsP and is grown to a layer thickness of about 80 angstroms. The other layers are grown by the conventionally-known methods.

The first and second barrier layers 3, 5 and the active layer 4 are grown in the growth conditions shown in the following table I. For comparison, the growth conditions for the GaInAs active layer to obtain an oscillation wavelength of 0.98 µm are also shown as "(Reference)."

According to the growth conditions shown in the following table I, the flow rates of TEGa (triethyl gallium) and TMIn (trimethyl indium) supplied from bubblers when the barrier layers 3, 5 are grown are controlled to the same amounts as those supplied when the active layer 4 is grown. On the other hand, the flow rates of AsH_3 and PH_3 when the barrier layers 3, 5 are grown are controlled differently from those supplied when the active layer 4 is grown. Predetermined growth times are set such that the thicknesses w_1, w_2 of the barrier layers 3, 5 are about 340 angstroms and the thickness d of the active layer 4 is about 80 angstroms. Also, the As:P composition ratio of the barrier layers 3, 5 are made different from that of the active layer 4. When these growth conditions are applied, an oscillation wavelength of about 0.98 µm can be obtained while the barrier layers 3, 5 have a energy band gap E_{g1} which is greater than the energy hand gap E_{g2} of the active layer 4 as shown in Fig. 1B on an enlarged scale . Accordingly, the carrier-confining efficiency can be improved.

TABLE I

	Flow rate of material (cc/m)				Growth time (sec)	Thickness (Å)
	TEGa (20°C)	TMIn (20°C)	AsH_3 (10%)	PH_3 (20%)		
GaInAsP barrier layer	50	40	60	500	115.6	340
GaInAsP well layer	50	40	300	200	27.8	80
(Reference) GaInAs well layer	50	25	300	0	29.8	80

Since the GaInAs active layer shown in the above table I as "(Reference)" does not contain P in the active layer, its condition for controlling the flow rate of TMIn differs from that of this embodiment.

Also, as shown in Fig. 1C on an enlarged scale, the barrier layers 3, 5 may have such a composition that receives, in close proximity to the active layer 4, a compression strain which is smaller than that applied to the active layer 4. In this composition, the close proximity portion can act as a strain-relieving layer which reduces the generation of defects resulting from the strain. Though a composition whose lattice can match that of the substrate is preferable in the proximity portion of the barrier layers 3, 5 in general, a part of the barrier layers 3, 5 may have such a composition that receives tensile strain so as to compensate for accumulated strain. Such a strain compensation is especially effective in cases where there are multiple quantum wells. While the strain-relieving layers are preferably placed on both sides of the active layer 4 as depicted, the above-mentioned effect can also be obtained when the strain-relieving layer is disposed on one side thereof alone.

In the semiconductor laser diode having the above-mentioned structure in accordance with this embodiment of the present invention, the following effects can further be obtained.

In general, when a material belonging to the V group is grown by AsH_3 and PH_3 in the process for making a semiconductor laser diode, their flow rates can be controlled relatively easily since they are gases and their flow rates to be supplied are large. On the other hand, when a material belonging to the III group is grown by TEGa and TMIn, they have to turn into gases by bubbling since they are intrinsically liquids. Accordingly, it is difficult to control their flow rates. Further, since their flow rates are set to small values, it takes a long time for the flow rates to be stabilized after being changed.

Therefore, as in the case of the prior art indicated as "(Reference)" in the above table I, when the flow rates of TEGa and TMIn have to be controlled by being switched between when the barrier layer is grown and when the active layer is grown, a long interval (interruption) is necessary for stabilizing the flow rates and thus the layers cannot be manufactured rapidly.

As shown in the above table I, on the other hand, in order to realize the thicknesses and compositions of the barrier layers 3, 5 and the active layer 4 for obtaining a desired oscillation wavelength in the structure in accordance with this

embodiment, it is sufficient for the flow rates of TEGa and TMIn to be constantly maintained (i.e. it is not necessary for their flow rates to be changed), while controlling the flow rates of AsH_3 and PH_3 which are easy to control, when the barrier layers 3, 5 and the active layer 4 are grown, since all these layers contain P.

Accordingly, when the semiconductor laser diode structure of this embodiment is applied, a long-time interruption of growth as in the case of the prior art is not necessary. Thus, the contamination on the surface during the interruption of growth can be minimized. While an interruption of several minutes is necessary in the prior art for the flow rates of TEGa and TMIn in a reactor to stabilize after being controlled by switching, it only takes an interruption of 3 seconds or less in this embodiment for the flow rates of AsH_3 and PH_3 in the reactor to stabilize after being controlled by switching. Thus, the time required for the manufacturing process can be shortened greatly. This advantageous effect can be obtained in the manufacturing processes of both OMVPE and MBE.

Also, the prior art has a problem that, when an active layer containing no P and a barrier layer containing P are grown, defects are likely to be introduced in the interface therebetween. In this embodiment, on the other hand, since all the barrier layers 3, 5 and the active layer 4 contain P, these defects can be reduced greatly so as to realize a semiconductor laser diode having a high reliability and an improved performance.

Fig. 2 shows a comparison of the characteristics of the semiconductor laser diode having a GaInAs active layer with the those of the semiconductor laser diode having a GaInAsP active layer in accordance with this embodiment as confirmed by the following experiments. The oscillation wavelength of each semiconductor laser diode is about 0.98 μm.

In the first place, an excitation current of 500 mA was supplied to a plurality of samples of semiconductor laser diodes at an ambient temperature of 25°C. Only those working correctly were selected from these samples and then subjected to a burn-in for 100 hours in which an excitation current of 275 mA was supplied thereto at an ambient temperature of 50°C.

While the ambient temperature is maintained at 50°C and the excitation current is set to 500 mA at maximum, the optical output characteristic with respect to the current was determined. The chart shows the COD levels (indicated as "o" in the drawing) and the maximum output levels (indicated as "□" in the drawing) of the laser diodes in which no COD occurred. As clearly shown in this chart, it has been empirically confirmed that the semiconductor laser diode having a GaInAsP active layer in accordance with this embodiment exhibits a characteristic which is clearly better than that of the semiconductor laser diode having GaInAs active layer.

In this embodiment, as a method for eliminating the difficulty in accurately controlling the growth of the active layer 4 having a thickness of 80 angstroms, the following technique may preferably be used. Namely, Fig. 3 shows the dependence of the room-temperature photoluminescence wavelength of the GaInAsP strained quantum well on the PH_3 flow rate obtained when the same conditions as those of GaInAsP of this embodiment are used except for the flow rate of PH_3 and the thickness. When such data are empirically be obtained and then the active layer of GaInAsP is grown on the basis of these data, a semiconductor laser diode having a desired oscillation wavelength can be manufactured even when the thickness d of the active layer is uncertain (i.e. it is not exactly the thickness of d=80 angstroms).

The composition ratio, the carrier concentration and the thickness of each layer are shown in table II.

TABLE II

	1. material 2. composition ratio 3. range 4. energy band gap: Eg	1. conduction type 2. dopant 3. carrier concentration at room temp. (cm^{-3}): n 4. range	1. thickness: d (nm) 2. range
substrate 1	1. Ga_xAs_y 2. X=1, Y=1 4. Eg=1.47eV	1. n-type 2. Si 3. $n=2x10^{18}$ 4. $1x10^{18}<n<4x10^{18}$	1. $d=70x10^3$ 2. $50x10^3<d<120x10^3$
cladding layer 2	1. $(Al_xGa_{1-x})_{0.5}In_{0.5}P$ 2. X=0 3. $0\leq x\leq 1$	1. n-type 2. Si 3. $n=1x10^{18}$ 4. $1x10^{17}\leq n \leq 2x10^{19}$	1. $d=2x10^3$ 2. $1x10^3\leq d\leq 2.5x10^3$

barrier layer 3	1.GaInAsP 4.Eg(barrier layer 3) <Eg(active layer 4)	1.n or p-type 2.undoped, Si or Zn 3.$n=5x10^{16}$ 4.$n<1x10^{17}$	1. d=34 2. 20≤d≤200
active layer 4	1.GaInAsP 4.Eg<1.47	1.n or p-type 2.undoped, Si or Zn 3.$n=5x10^{16}$ 4.$n<1x10^{17}$	1. d=8 2. 2≤d≤15, (d < critical thick-ness)
barrier layer 5	1.GaInAsP 4.Eg(barrier layer 3) <Eg(active layer 4)	1.n or p-type 2.undoped, Si or Zn 3.$n=5x10^{16}$ 4.$n<1x10^{17}$	1. d=34 2. 20≤d≤200

current-blocking layer 10	1. $(Al_xGa_{1-x})_{0.5}In_{0.5}P$ 2. X=0.2 3. $0\le x\le 1$	1. n-type 2. Si 3. $n=5x10^{17}$ 4. $1x10^{17}\le n \le 2x10^{18}$	1. d= $1.6x10^3$ 2. $0.2x10^3 \le d\le 2x10^3$
coating layer 13	1. GaAs or $Ga_{0.5}In_{0.5}P$	1. n or p-type 2. undoped,.Si or Zn 3. $n=5x10^{16}$ 4. $n<1x10^{17}$	1. d= $0.1x10^3$ 2. $0.05x10^3 \le d\le 3x10^3$

In the following, the second embodiment of the present invention will be explained with reference to Figs. 4 and 5. In this embodiment, the composition ratio of a part of the cladding layers 2, 6 shown in Fig. 1A is changed so as to generate an energy band gap E_g shown in Fig. 4, while the rest of layer structure (the first and second barrier layers 3, 5 and the active layer 4, in particular) are the same as those of the first embodiment. Namely, the main portion of the cladding layers 2, 6 is composed of $(Al_{0.1}Ga_{0.9})_{0.5}In_{0.5}P$, while $(Al_{0.9}Ga_{0.1})_{0.57}In_{0.43}P$ is grown in a part of the cladding layer 2 so as to realize a wide energy band yap E_g. Since such a wide energy band gap is set, carriers in the active layer 4 are prevented from overflowing. Also, since the In composition in this part of the layer is set low to receive tensile strain, the barrier effect with respect to the carriers is increased.

Further, since this part of the layer does not directly contact with the active layer 4 but the same energy band gap as that in the rest of the cladding layer 2 is interposed therebetween, carrier loss is prevented.

Fig. 5 shows the configuration of an apparatus for making the semiconductor laser diode having the structure explained above. The systems for supplying AsH_3 and PH_3 are not depicted in this drawing. This apparatus has a first bubbler 1, which applies OMVPE and is used for growing the cladding layers 2, 6 containing Al, and a second bubbler 12, which is independent from the first bubbler 11 and used for growing the first and second barrier layers 3, 5 and active layer 4 containing no Al.

By way of a switching device 13, the bubblers 11, 12 are piped to a reactor 15. Also, a bypass pipe 14 is connected to the switching device 13. Exhaust is discharged at the ends of the reactor 15 and bypass pipe 14.

In the first place, in order to grow the cladding layer 2, the switching device 13 is switched so as to connect the first bubbler 11 to the reactor 15 while disconnecting the second bubbler 12. The cladding layer 2 containing Al shown in Fig. 4 is thus grown. Then, the second bubbler 12 is connected to the reactor 15 while disconnecting the first bubbler 11. The first and second barrier layers 3, 5 and active layer 4 containing no Al shown in Fig. 4 are thus grown.

Thereafter, the switching device 13 is switched so as to connect the first bubbler 11 to the reactor 15 while disconnecting the second bubbler 12. The cladding layer 6 containing Al shown in Fig. 4 is thus grown. The rest of the layers are grown by the conventional OMVPE method.

Since the two systems of the first and second bubblers 11, 12 are switched by the switching device 13, the flow rate of each material can be controlled more accurately than the case where a single bubbler system is applied so as to attain the same object.

When an active layer is grown as GaInAs having a thickness of about 80 angstroms and then, with its Ga:In composition ratio, a GaInAsP barrier layer is grown such that its lattice matches that of a substrate, the energy band gap of the barrier layer becomes so small that the original effect of the barrier may be reduced.

On the other hand, when the GaInAsP active layer of the present invention is applied, the energy band gap of the GaInAsP barrier layer can become large even when the Ga:In composition ratio is made constant. When the compositions of Ga and In in the active and barrier layers can be made substantially the same, the amounts of supply of Ga and In can be maintained at constant levels.

Accordingly, advantageous effects can be obtained in the manufacture in that manufacturing steps can be simplified and so forth.

From the invention thus described, it will be obvious that the invention may be varied in many ways. Such variations are not to be regarded as a departure from the spirit and scope of the invention, and all such modifications as would be obvious to one skilled in the art are intended for inclusion within the scope of the following claims.

The basic Japanese Application No. 210097/1994 (6-210097) filed on September 2, 1994, is hereby incorporated by reference.

Claims

1. A semiconductor laser diode comprising:
   a substrate of GaAs; and
   an active layer formed on said substrate, having a GaInAsP strained quantum well whose energy band gap is smaller than that of GaAs.

2. A semiconductor laser diode according to claim 1, further comprising a barrier layer of GaInAsP whose energy band gap is greater than that of said active layer.

3. A semiconductor laser diode according to claim 2, wherein said active layer and said barrier layer have the same composition ratio of Ga to In.

4. A semiconductor laser diode according to claim 3, wherein said barrier layer has such a structure that receives, in close proximity to said active layer, a compressive strain which is smaller than that applied to said active layer.

5. A semiconductor laser diode according to claim 1, further comprising a pair of cladding layers which sandwich a portion including said barrier layer and active layer, wherein said portion and said cladding layers are comprised of material containing P.

6. A semiconductor laser diode according to claim 1, further comprising a semiconductor window layer provided on a cleavage plane of said active layer, wherein the energy band gap of said semiconductor window layer is greater than that of said active layer.

7. A semiconductor laser diode according to claim 1, wherein said semiconductor laser diode has an oscillation wavelength at room temperature set not shorter than 0.96 μm.

8. A method of making a semiconductor laser diode, comprising the steps of:
   forming a cladding layer on a GaAs substrate;
   supplying Ga and In on said cladding layer with a first ratio of Ga to In to form a barrier layer on said cladding layer; and
   supplying Ga and In on said barrier layer with said first ratio to form an active layer on said barrier layer.

Fig. 2

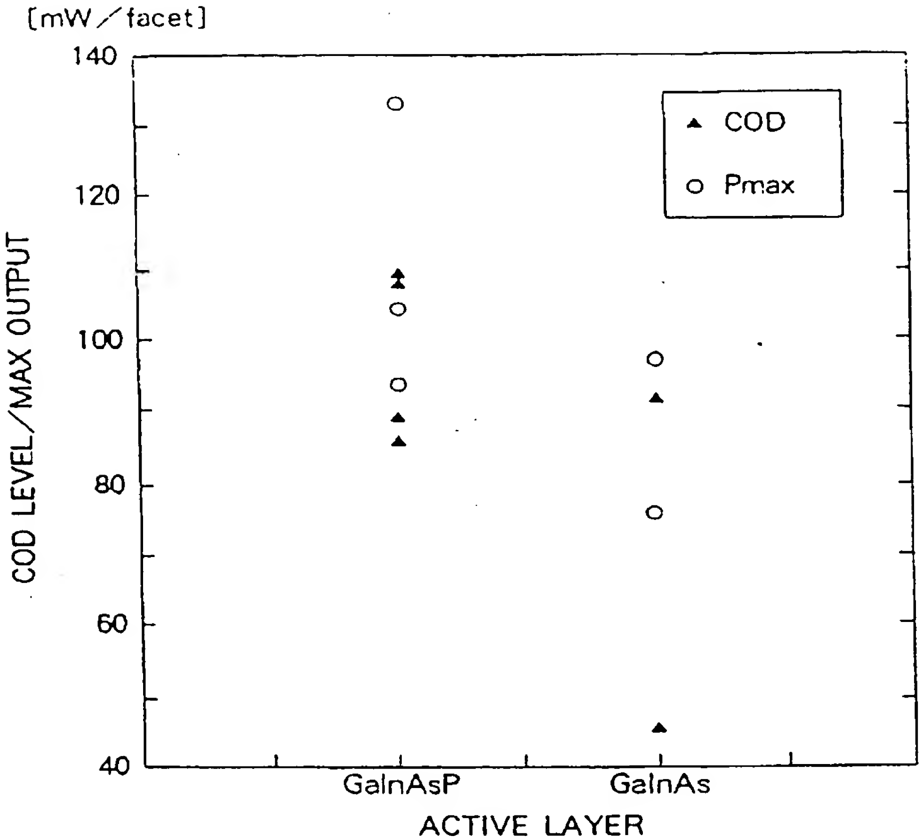

[mW/facet]
140
120
100
80
60
40
COD LEVEL/MAX OUTPUT
COD
Pmax
GaInAsP
GaInAs
ACTIVE LAYER

Fig. 3

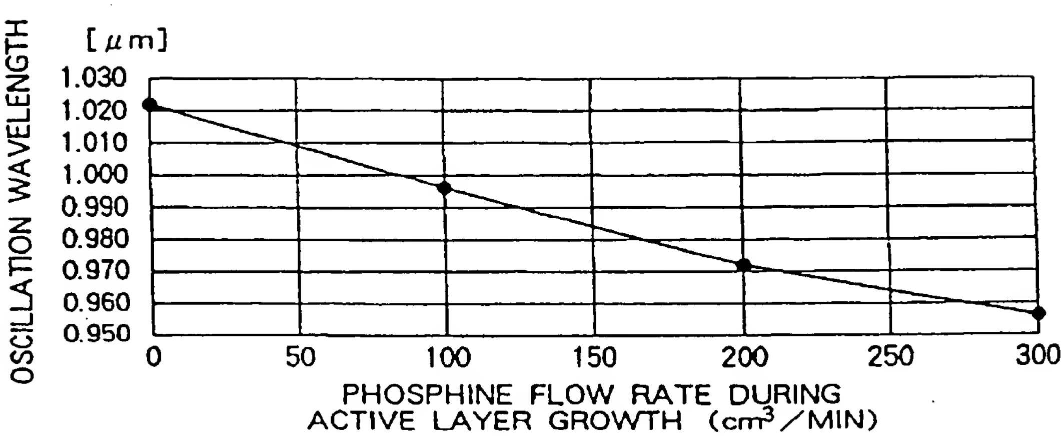
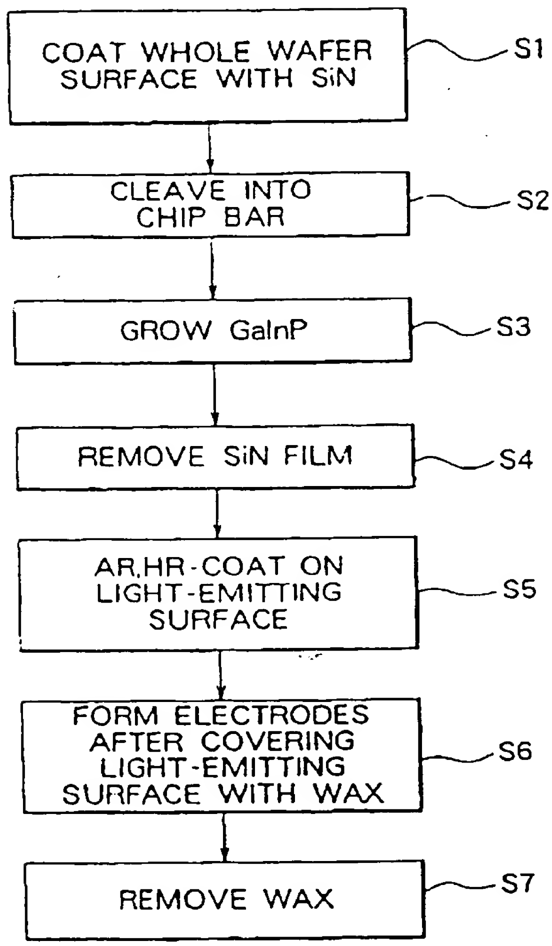

OSCILLATION WAVELENGTH
[μm]
1.030
1.020
1.010
1.000
0.990
0.980
0.970
0.960
0.950
0
50
100
150
200
250
300
PHOSPHINE FLOW RATE DURING
ACTIVE LAYER GROWTH (cm³/MIN)

Fig. 6


COAT WHOLE WAFER SURFACE WITH SiN
S1
CLEAVE INTO CHIP BAR
S2
GROW GaInP
S3
REMOVE SiN FILM
S4
AR,HR-COAT ON LIGHT-EMITTING SURFACE
S5
FORM ELECTRODES AFTER COVERING LIGHT-EMITTING SURFACE WITH WAX
S6
REMOVE WAX
S7

(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 701 309 A3

(12) **EUROPEAN PATENT APPLICATION**

(88) Date of publication A3:
08.05.1996 **Bulletin 1996/19**

(43) Date of publication A2:
13.03.1996 **Bulletin 1996/11**

(21) Application number: 95113765.2

(22) Date of filing: 01.09.1995

(51) Int. Cl.[6]: **H01S 3/19**, H01L 33/00, H01S 3/085

(84) Designated Contracting States:
DE FR GB

(30) Priority: 02.09.1994 JP 210097/94

(71) Applicant: SUMITOMO ELECTRIC INDUSTRIES, LTD.
Osaka-shi, Osaka 541 (JP)

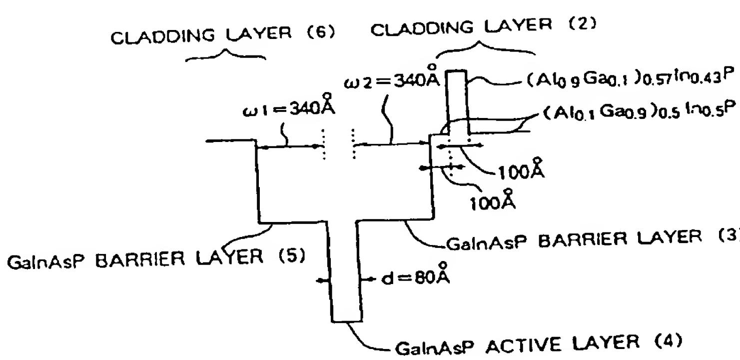
(72) Inventors:
- Katsuyama, Tsukuru, c/o Yokohama Works Yokohama-shi, Kanagawa 244 (JP)
- Yoshida, Ichiro, c/o Yokohama Works Yokohama-shi, Kanagawa 244 (JP)
- Hashimoto, Jun-ichi, c/o Yokohama Works Yokohama-shi, Kanagawa 244 (JP)
- Murata, Michio, c/o Yokohama Works Yokohama-shi, Kanagawa 244 (JP)

(74) Representative: Lehn, Werner, Dipl.-Ing. et al
Hoffmann, Eitle & Partner,
Patentanwälte,
Arabellastrasse 4
81925 München (DE)

(54) Semiconductor laser diode

(57) A semiconductor laser diode which can be applied to optical fiber amplifiers to attain a high reliability and can generate light having a wavelength of about 1 μm is provided. This semiconductor laser diode is formed on a GaAs substrate and has an active layer comprising a GaInAsP strained quantum well whose energy band gap is smaller than that of GaAs. Barrier layers each comprising GaInAsP whose band gap is greater than that of the active layer are bonded to the active layer through heterojunction. According to this structure, when the active layer and the barrier layers are grown, the amounts of supply of a Ga material and an In material can be controlled in a simple manner and a semiconductor laser diode having a high reliability can be realized.

Fig. 4



EP 0 701 309 A3

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 95 11 3765

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
A	JOURNAL OF CRYSTAL GROWTH, vol.127, no.1/4, 3, AMSTERDAM NL pages 1033 - 1036, XP000441216 G.ZHANG ET AL 'GSMBE growth of InGaAsP on GaAs substrates and it's application to 0.98 mum lasers' * the whole document * ---	1-5,7	H01S3/19 H01L33/00 H01S3/085
A	APPLIED PHYSICS LETTERS, vol.62, no.10, 8 March 1993 pages 1062 - 1064, XP000345976 GARBUZOV D Z ET AL 'HIGH-POWER BURIED INGAASP/GAAS (=0.8 UM) LASER DIODES' * the whole document * ---	1-5	
A	APPLIED PHYSICS LETTERS, vol.65, no.7, 15 August 1994, NEW YORK US pages 892 - 894, XP000464561 G-J. SHIAU ET AL 'Low threshold 1.3 mum wavelength InGaAsP strained layer multiple quantum well lasers grown by gas source molecular beam epitaxy' * the whole document * ---	1-5	TECHNICAL FIELDS SEARCHED (Int.Cl.6) H01S
A	ELECTRONICS LETTERS, vol.30, no.7, 31 March 1994, STEVENAGE GB pages 563 - 565, XP000438281 T. UCHIDA ET AL '1.3 mum InGaAs/GaAs strained quantum well lasrs with InGaP cladding layer' * the whole document * ---	1-5	
D,P, A	US-A-5 384 151 (RAZEGHI MANIJEH) 24 January 1995 * the whole document * -----	1-5	

~~The present search report has been drawn up for all claims~~

Place of search	Date of completion of the search	Examiner
THE HAGUE	20 December 1995	CLAESSEN, L

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

European Patent Office

CLAIMS INCURRING FEES

The present European patent application comprised at the time of filing more than ten claims.

☐ All claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for all claims.

☐ Only part of the claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for the first ten claims and for those claims for which claims fees have been paid.

namely claims:

☐ No claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for the first ten claims.

LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirement of unity of invention and relates to several inventions or groups of inventions.

namely:

see sheet -B-

☐ All further search fees have been paid within the fixed time limit. The present European search report has been drawn up for all claims.

☐ Only part of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the inventions in respect of which search fees have been paid.

namely claims:

☒ None of the further search fees has been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims.

namely claims: 1-7

European Patent Office

EP 95 11 3765 -B-

LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirement of unity of invention and relates to several inventions or groups of inventions, namely:

1. Claims 1-7: A semiconductor laserdiode on a GaAs substrate having a strained InGaAsP quantum well active layer with a bandgap smaller than that of GaAs
2. Claim 8 : A method of making a semiconductor laserdiode having in different layers the same ratio of In to Ga